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Appendix A – Excerpt from Web Page entitled,
"Spatial Filters - Median Filter"

found at http://www.cee.hw.ac.uk/hipr/html/median.html

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Median Filter

Common Names: Median filtering, Rank filtering

Brief Description

The median filter is normally used to reduce noise in an image, somewhat like the mean filter. However, it often does a better job than the mean filter of preserving useful detail in the image.

How It Works

Like the mean filter, the median filter considers each pixel in the image in turn and looks at its nearby neighbours to decide whether or not it is representative of its surroundings. Instead of simply replacing the pixel value with the *mean* of neighbouring pixel values, it replaces it with the *median* of those values. The median is calculated by first sorting all the pixel values from the surrounding neighbourhood into numerical order and then replacing the pixel being considered with the middle pixel value. (If the neighbourhood under consideration contains an even number of pixels, the average of the two middle pixel values is used.) Figure 1 illustrates an example calculation.

123	125	126	130	140
122	124	126	127	135
118	120	150	125	134
119	115	119	123	133
111	116	110	120	130

Neighbourhood values:

115, 119, 120, 123, 124,
125, 126, 127, 150

Median value: 124

Figure 1 Calculating the median value of a pixel neighbourhood. As can be seen the central pixel value of 150 is rather unrepresentative of the surrounding pixels and is replaced with the median value: 124. A 3×3 square neighbourhood is used here — larger neighbourhoods will produce more severe smoothing.

Guidelines for Use

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Spatial Filters - Median Filter

By calculating the median value of a neighbourhood rather than the mean filter, the median filter has two main advantages over the mean filter:

- The median is a more robust average than the mean and so a single very unrepresentative pixel in a neighbourhood will not affect the median value significantly.

- Since the median value must actually be the value of one of the pixels in the neighbourhood, the median filter does not create new unrealistic pixel values when the filter straddles an edge. For this reason the median filter is much better at preserving sharp edges than the mean filter.

 shows an image that has been corrupted by Gaussian noise with mean 0 and standard deviation (SD) 8. The original image is for comparison. Applying a 3×3 median filter produces . Note how the noise has been reduced at the expense of a slight degradation in image quality. shows the same image with even more noise added (Gaussian noise with mean 0 and SD 13), and is the result of 3×3 median filtering. The median filter is sometimes not as subjectively good at dealing with large amounts of Gaussian noise as the mean filter.

Where median filtering really comes into its own is when the noise produces extreme 'outlier' pixel values, as for instance in which has been corrupted with 'salt and pepper' noise - *i.e.* bits have been flipped with probability 1%. Median filtering this with a 3×3 neighbourhood produces , in which the noise has been entirely eliminated with almost no degradation to the underlying image. Compare this with the similar test on the mean filter.

Consider another example wherein the original image has been corrupted with higher levels (*i.e.* p=5% that a bit is flipped) of salt and pepper noise . After smoothing with a 3×3 filter, most of the noise has been eliminated . If we smooth the noisy image with a larger median filter, *e.g.* 7×7, all the noisy pixels disappear, as shown in . Note that the image is beginning to look a bit 'blotchy', as greylevel regions are mapped together. Alternatively, we can pass a 3×3 median filter over the image three times in order to remove all the noise with less loss of detail .

In general, the median filter allows a great deal of high spatial frequency detail to pass while remaining very effective at removing noise on images where less than half of the pixels in a smoothing neighbourhood have been effected. (As a consequence of this, median filtering can be less effective at removing noise from images corrupted with Gaussian noise.)

One of the major problems with the median filter is that it is relatively expensive and complex to compute. To find the median it is necessary to sort all the values in the neighbourhood into numerical order and this is relatively slow, even with fast sorting algorithms such as *quicksort*. The basic algorithm can however be enhanced somewhat for speed. A common technique is to notice that when the neighbourhood window is slid

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across the image, many of the pixels in the window are the same from one step to the next, and the relative ordering of these with each other will obviously not have changed. Clever algorithms make use of this to improve performance.

Exercises

1. Using the image , explore the effect of median filtering with different neighbourhood sizes.

2. Compare the relative speed of mean and median filters using the same sized neighbourhood and image. How does the performance of each scale with size of image and size of neighbourhood?

3. Unlike the mean filter, the median filter is non-linear. This means that for two images $A(x)$ and $B(x)$:

$$median[A(x) + B(x)] \neq median[A(x)] + median[B(x)]$$

Illustrate this to yourself by performing smoothing and pixel addition (in the order indicated on each side of the above equation!) to a set of test images. Carry out this experiment on some simple images, e.g. and

References

R. Boyle and R. Thomas *Computer Vision: A First Course*, Blackwell Scientific Publications, 1988, pp 32 - 34.

E. Davies *Machine Vision: Theory, Algorithms and Practicalities* Academic Press, 1990, Chap 3.

A. Marion *An Introduction to Image Processing*, Chapman and Hall, 1991, p 274.

D. Vernon *Machine Vision*, Prentice-Hall, 1991, Chap 4.

Local Information

General advice about the local HIPR installation is available here

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Hypermedia Image Processing Reference

http://www.cee.hw.ac.uk/hipr/html/median.html

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